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UNION OF SOUTH AFRICA

DEPARTMENT OF COMMERCE AND INDUSTRIES

DIVISION OF FISHERIES
INVESTIGATIONAL REPORT No. 38

THE SOUTH AFRICAN PILCHARD
(Sardinops ocellata)

TRENDS IN THE PILCHARD FISHERY OF THE UNION OF SOUTH AFRICA, 1943-58

BY

C. G. DU PLESSIS

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6527125—2

1. Abstract.

The history of the commercial fishery for pilchards (*Sardinops ocellata*) off the west and south coasts of the Union of South Africa falls into two phases, namely, a period of unrestricted fishing (1943–49) followed by one of regulated fishing (1950–58). This paper is mainly concerned with the latter phase during which various legal control measures were applied. In describing the history of the fishery, these measures are listed chronologically and the reasons for their adoption are explained.

Detailed statistics of the commercial catch are given and then an analysis is made of the effects of certain man-made factors on trends in the catch during 1950–58. The first factor examined is the legal regulation of the fishery. Then the influences of economic and technological factors are considered. The conclusion is reached that the combined effect of these abiotic factors on the trend of the catch cannot be readily assessed during the first two years of regulated fishing. For the remaining seven years (1952–58) an assessment is possible and it is found that the catch trend is a reasonably undistorted reflection of the relative availability of pilchards to the fishery.

The last section of the paper deals with correlations between the availability of pilchards and certain natural factors during 1952–58. Relationships of apparent significance are found to exist between the availability of pilchards and the following:—

(i) Spawning intensity.

(ii) The relative abundances of phyto- and zooplankton.

(iii) Sea temperature.

The relationship between availability and sea temperature can be used as a basis for forecasting the pilchard catch.

2. Introduction.

This paper is an attempt to correlate the data that the Division of Fisheries has gathered in respect of the natural and man-made factors affecting the pilchard fishery of the Union of South Africa.

Being a contribution to a World Scientific Meeting on the Biology of Sardines and Related Species, which was held under the auspices of the United Nations' Food and Agriculture Organization, the paper had to conform to certain specifications. The fact that the text was not to exceed five thousand words has necessitated a thorough screening of data and has caused the subject matter to be restricted to bare essentials.

As stipulated by the FAO, all units of measurement are given in the metric system. In order to express the relevant statistics in the customary South African units, the following conversion ratios should be used: 0·90718 metric ton=1 short ton, 1·60935 kilometre=1 mile, 25·40 millimetres=1 inch.

3. Geographic Data.

1. The range of the South African pilchard, *Sardinops ocellata* (Pappé).

The occurrence of *S. ocellata*, as indicated by evidence obtained from investigations carried out by the author's institution, extends from the latitude of the Kunene River on the west coast, round the Cape of Good Hope, to the latitude of Durban on the east coast of Southern Africa (see Fig. 1).

The length of coastline along which this species may be encountered is *circa* 3,500 kilometres, but the total distance over which dense shoals appear close inshore amounts to only 720 Km. This area of concentrated occurrence is made up of the three stretches of coastal waters marked A, B and C in Fig. 1. The approximate distance between A and B is 1,000 Km. whilst from B to C it is 1,100 Km.

2. The commercial fishing areas.

(i) *Area A.*

This is known as the Walvis Bay area and covers *circa* 150 Km. of coastline, from 50 Km. south to 100 Km. north of Walvis Bay.

The fishery in area A is not dealt with in this paper.

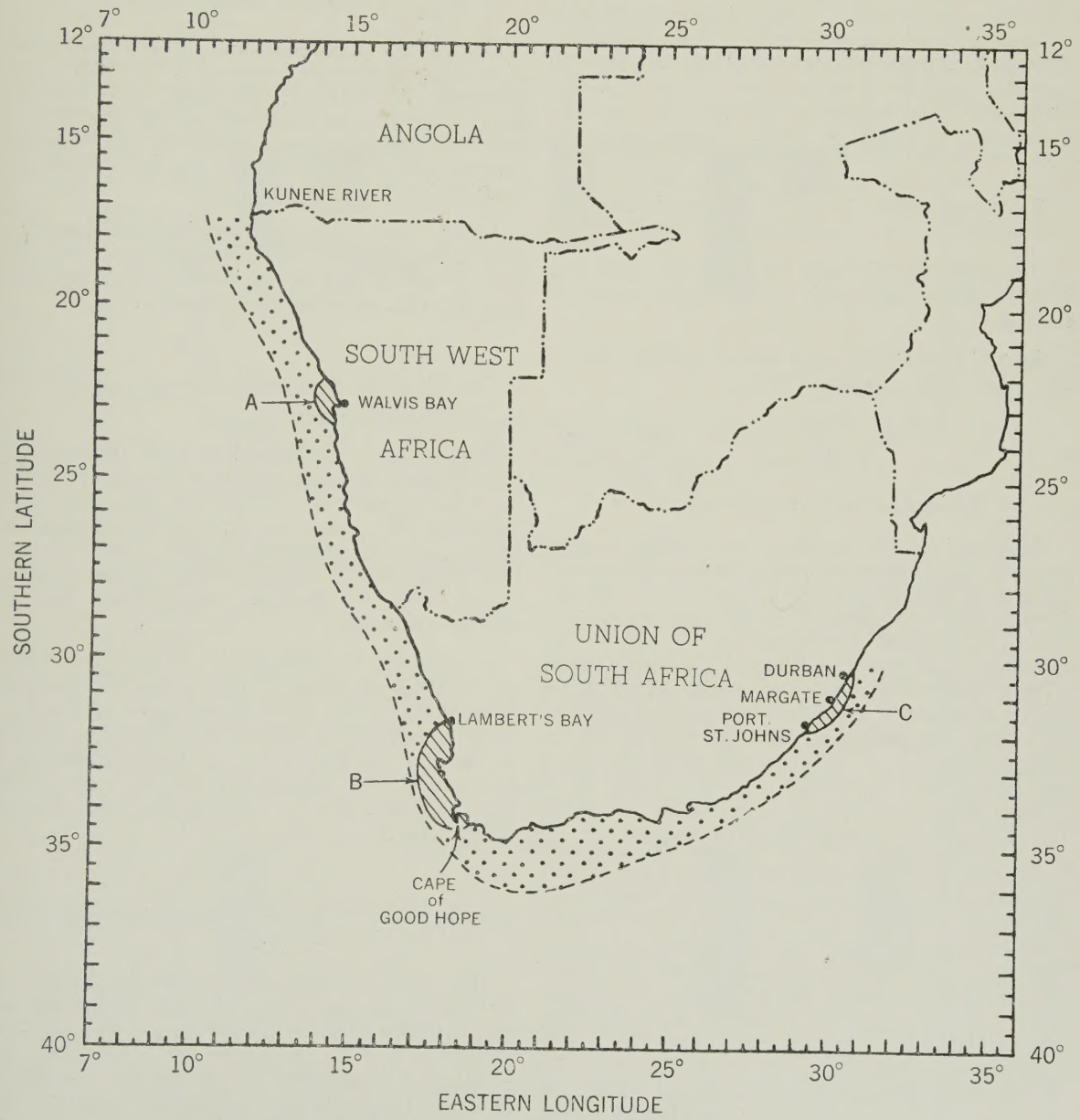
(ii) *Area B.*

This area has generally been referred to as the St. Helena Bay fishing grounds because, when commercial fishing for pilchards in South African waters began in 1943, it was confined to St. Helena Bay and its immediate vicinity. In the course of time fishing operations extended farther southward and today the fishing fleet exploits the inshore area

from a little north of Lambert's Bay, southward round the Cape of Good Hope as far as Cape Hangklip (the eastern boundary of False Bay), i.e. a distance of *circa* 320 Km. (see also Fig. 10).

Boats operating in this area fish up to 80 Km. offshore and use lampara nets of the type described by du Plessis (1958). The majority of catches are made within 40 Km. of the coast.

FIGURE 1



DISTRIBUTION CHART AND AREAS OF COMMERCIAL FISHING FOR Sardinops ocellata

Trigsurvey, 1959. Government Printer, 1959.

(iii) *Area C.*

Compared with areas A and B, the commercial fishing in area C is negligible. Pilchard shoals appear inshore at Port St. Johns (see Fig. 1) in June each year and move in a north-easterly direction as far as Durban where they disappear from the coastal waters. The further movements of these shoals are unknown. Their migration through the inshore waters along this 250 Km. of coastline lasts only about three weeks and the shoals are fished by means of beach seine nets for a few days at a time at various points along the 120 Km. stretch of coast between Margate and Durban. On the average the total duration of fishing in this area is 10 days per annum and the estimated total catch is less than 100 tons.

No catch statistics are kept for this area and little is known about the natural environment of the fish.

Area C is not dealt with further and the rest of this paper refers to area B only.

4. History.

1. Period of unrestricted fishing, 1943–49.

Although public attention was drawn to the presence of large shoals of pilchards and maasbanker [*Trachurus trachurus* (Linné)], in the St. Helena Bay area about 30 years ago, commercial fishing in this area started only in 1943 under the stimulus of a war-time demand for canned fish. The catch during 1943 was estimated at 6,500 metric tons and it was processed into canned fish, fish meal and fish oil by two factories on the St. Helena Bay coast. During the following years factories grew in number and size while more fishing boats entered the fishery, with the result that the catch increased rapidly each year.

Despite the fact that there were no legal restrictions on the expansion of the fishery in those days, the boats and factories nevertheless had to be licensed by the state institution responsible for the control of the sea fisheries of the Union of South Africa, namely, the Division of Fisheries of the Department of Commerce and Industries. No official catch statistics were kept, but it was possible to estimate the catches from the quantities of fish meal and canned fish produced. Thus the catch for 1949 was estimated at 113,000 metric tons of pilchards and maasbanker, of which about 68,000 tons were pilchards.

The rapid growth of the fishery was by then causing the Division of Fisheries some concern and it was thought advisable to regulate the development in order to protect the resources and to guard against an unstable economy within the fishery.

2. Period of restricted fishing, 1950–58.

This period is characterised by the imposition of a series of control measures. These were not enforced unilaterally by the State, each measure being adopted after consultation with the processors and fishermen via a Fisheries Development Advisory Council, a fully representative statutory body called into being in 1944.

A great deal of thought and discussion accompanied the adoption of the control measures, but here it will suffice to list them chronologically together with brief clarifying remarks.

(i) *The provision of a minimum mesh size for pilchard fishing nets.*

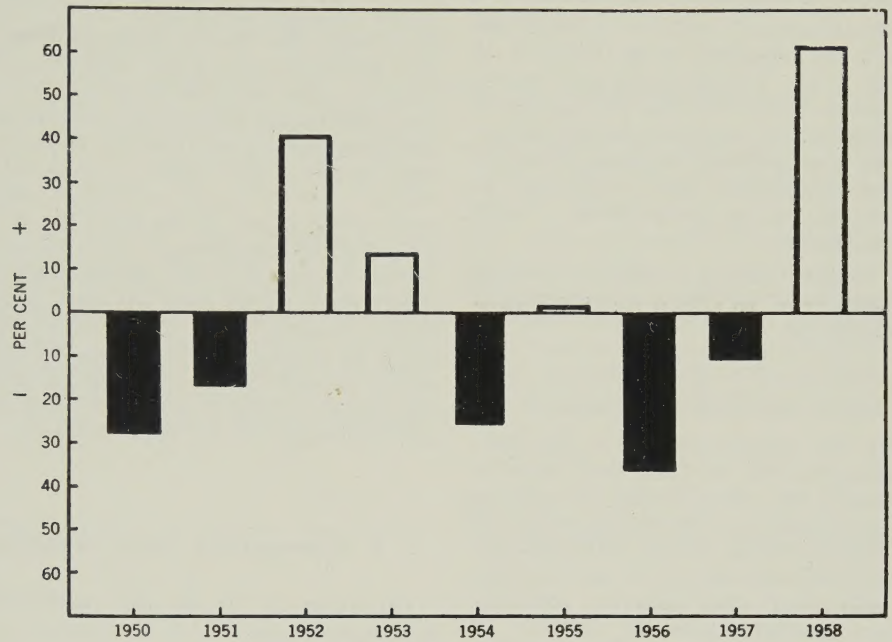
This measure, introduced in 1950, prescribed a size of 38 mm. between knots with the mesh closed, i.e. a bar measurement of 19 mm. The prescribed minimum was reduced to 32 mm. closed mesh or 16 mm. bar measurement in 1956. This was the year during which synthetic fibre netting had replaced virtually all the cotton used as a net material in previous years.

In practice, the decrease in the prescribed size of mesh did not bring about a material reduction in its effective size, because the mesh of the previously used cotton netting had invariably shrunk to 32 mm. or less after successive preservative treatments. The synthetic netting, on the other hand, retained or even increased its size of mesh while in use.

(ii) *The limitation of plants producing fish meal, fish oil and fish fertilizer.*

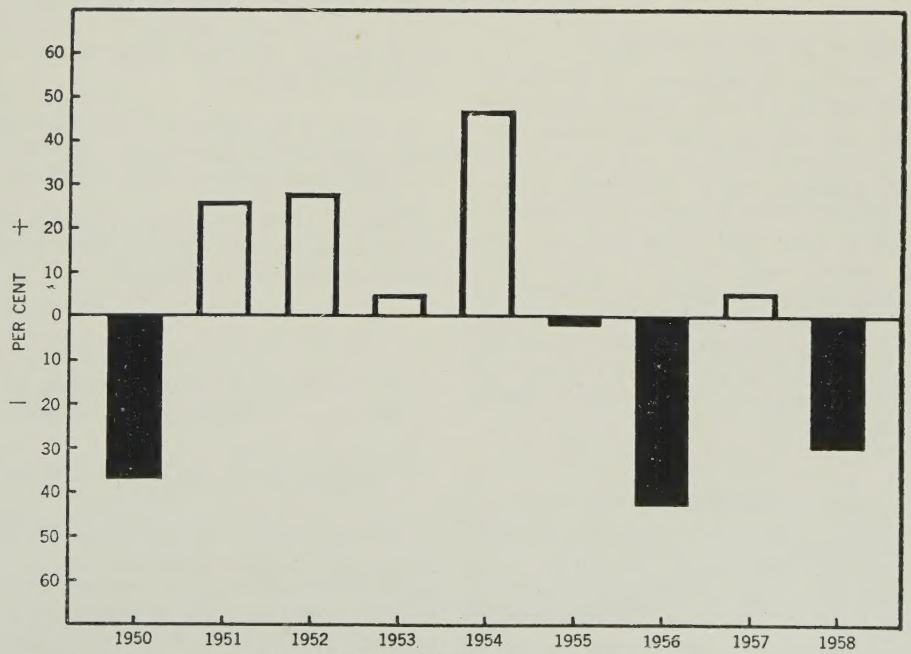
This measure became law towards the end of 1950 and it limited reduction plants to the number and capacity of those plants already in existence. Provision had to be made for authorizing the erection of a few additional plants not actually in existence but for which irrevocable financial commitments had been incurred prior to the promulgation of the regulation. The practical result was that the over-all reduction capacity in the fishery reached the permitted maximum of 221 metric tons of raw fish per hour only in 1953.

FIGURE 2



PERCENTAGE DEVIATION FROM AVERAGE ANNUAL CATCH OF PILCHARDS, 1950–58

FIGURE 3



PERCENTAGE DEVIATION FROM AVERAGE ANNUAL CATCH OF MAASBANKER, 1950–58

6527125—3

(iii) *The declaration of a closed fishing season.*

A programme of intensive research on the South African pilchard was launched by the Division of Fisheries during 1950. The data obtained during that year confirmed earlier findings that pilchards were ordinarily spawning and in a poor condition for industrial processing during the spring months. It was therefore agreed that from 1951 onwards there would be no fishing for pilchards during September and October.

The annual closure during these two months was observed until 1954. In 1955 it was superseded by control measure (vi).

(iv) *The limitation of boats fishing for pilchards.*

This measure was adopted in 1953 at the insistence of the fishermen who felt that, since factories had been limited by law, there should be a corresponding legal prohibition on the admission of new boats to the fishery, which already had sufficient boats. A boat limitation committee was formed, consisting of fishermen's and factories' representatives in equal numbers, with the Director of Fisheries as chairman. The committee's policy was to permit no increase in the numerical strength or in the total hold capacity of the pilchard fishing fleet.

(v) *The limitation of pilchard canneries.*

Subsequent to the prohibition on reduction plants a small number of new fishing companies decided to take the risk of erecting canning factories despite the fact that they had no licences for operating supplementary reduction plants. They soon discovered that a cannery without the means to process offal and reject fish was not economically sound and, as the government authorities firmly refused to grant them reduction plant licences, they were forced to throw in their lot with other concerns better placed than themselves. This episode led to the decision to peg the number of pilchard canneries, the limitation taking effect at the end of 1953.

(vi) *The imposition of a maximum annual catch.*

This measure was adopted in 1953 by voluntary agreement with the commercial fishery interests. The catch quota was fixed at 226,900 metric tons (250,000 short tons) of pilchards *and* maasbanker per annum with the proviso that, should the quota be reached before the end of August in any year, fishing would nevertheless continue until 31st August of that year.

NOTE.—The pilchard fishery of the Union of South Africa is so closely interwoven with the maasbanker fishery that it is common practice to refer to the two as a single " pilchard/maasbanker fishery ". The two species are caught in the same area, often at the same time a few kilometres apart and fishermen receive the same price for catches of both species. For these reasons all the above control measures were applied in respect of the maasbanker as well as the pilchard. A catch quota for pilchards, as distinct from maasbanker, was considered inpracticable, mainly because such an arrangement would have left the " pilchard/maasbanker fishery " with very little of the flexibility which it needed for counteracting the economic shocks caused by the considerable fluctuations in the catches of the two species from year to year (see Tables III and IV, Figs. 2 and 3).

5. Commercial Catch Statistics.

On pages 23 to 26 the reader will find six tables giving statistics of the fishery.

Table I shows the monthly catches of pilchards and maasbanker delivered to factories during 1950–58.

In Tables II, III and IV the ratios between pilchard and maasbanker catches are given as well as the annual deviations from the average catches of these two species.

In Table V the annual pilchard catches are compared with fishing fleet and processing plant capacities and with lengths of fishing season.

Table VI gives the size composition of the annual pilchard catches and the nine-year average composition for the period 1950–58.

6. Correlations between Trends in the Catch and Certain Man-made Factors, 1950–58.

1. Legal regulation and the trend in the size of the catch.

The examination of the effect of the legal regulation of the pilchard fishery on the trend in the catch is complicated by the fact that the control measures embrace the pilchard and maasbanker fisheries collectively. Fortunately the trend in the pilchard catch corresponds well with the trend shown by the combined pilchard and maasbanker catch (see Tables I and II, Fig. 4). The average

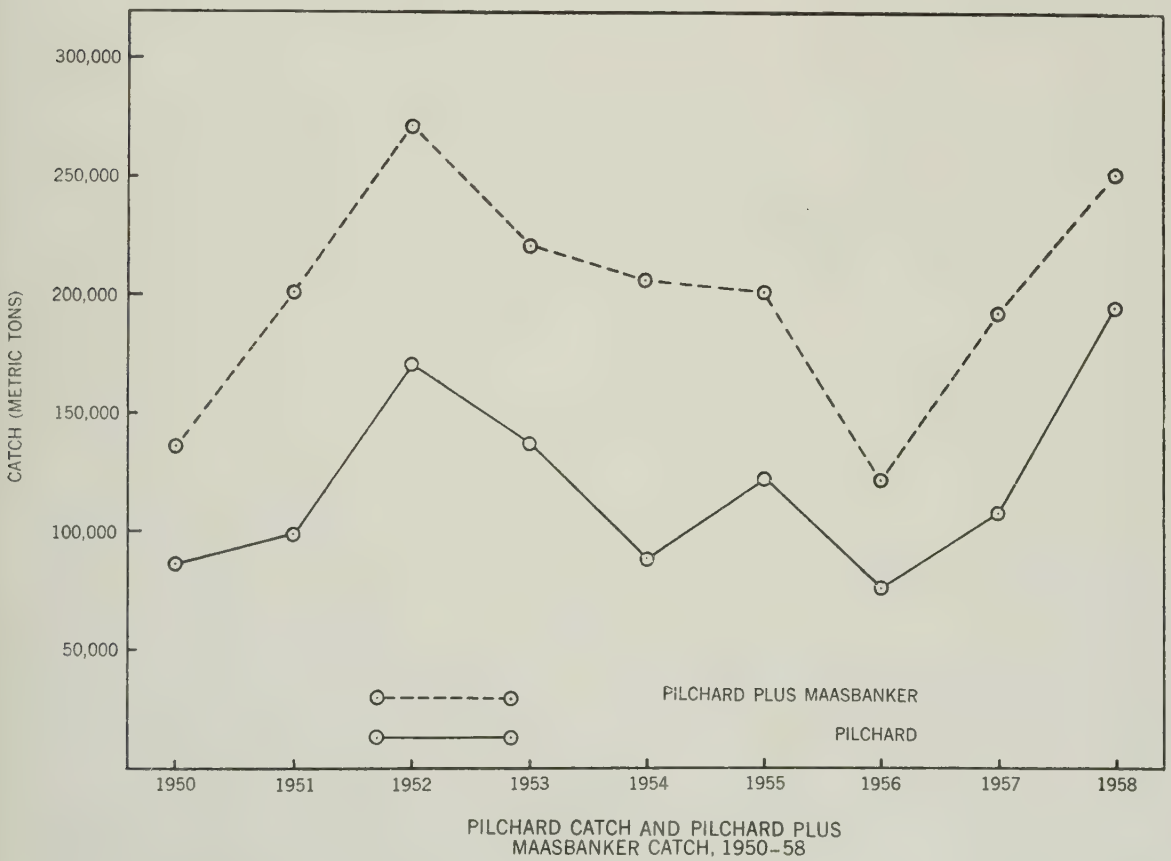
ratio of the pilchard catch to the maasbanker catch for the nine years in question is 60:40 and from Table II it is seen that the annual ratios are not too widely scattered about the nine-year average, the two notable exceptions being 1954 and 1958. In 1954 economic factors were largely responsible for disturbing the ratio (see section 3 of this chapter), whilst in 1958 there was an unprecedented abundance of small pilchards in the fishing area (see Fig. 8).

The relatively constant ratio between the pilchard catch and the combined pilchard and maasbanker catch permits the assumption to be made that the general trend of the pilchard catch would have been influenced similarly by the control measures, had these been applied in respect of the pilchard fishery individually instead of on the pilchard and maasbanker fisheries collectively. It is therefore possible to treat the control measures as if they applied to the pilchard fishery as a separate entity.

(i) *The mesh size of fishing nets.*

Since the effective mesh size of netting remained virtually unchanged throughout the period 1950–58, it is difficult to assess the influence of this control measure on the trend in the catch. It is possible that mesh sizes materially smaller or larger than the 32 mm. actually in use would have resulted in different trends in the catch. However, the only certainty about this matter is that for the particular mesh size of 32 mm. the trend in the pilchard catch, comprising fish of standard lengths not less than 14 cm. (see Table VI, Fig. 8), was as shown in Fig. 4.

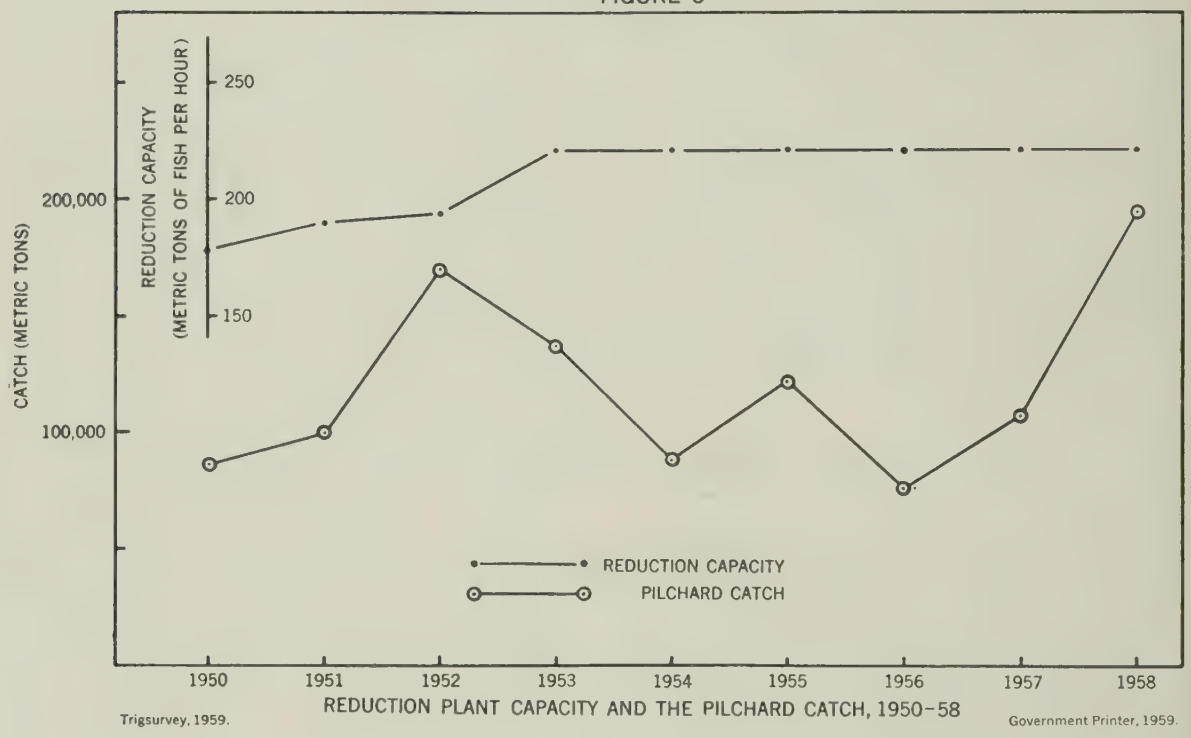
FIGURE 4



PILCHARD CATCH AND PILCHARD PLUS MAASBANKER CATCH, 1950–58

Trigsurvey, 1959. Government Printer, 1959.

FIGURE 5



REDUCTION PLANT CAPACITY AND THE PILCHARD CATCH, 1950–58

(ii) *The limitation of reduction plant capacity.*

Fig. 5 shows the total reduction capacity of the factories operating during each year and the pilchard catch in that year. It is seen that from 1950 to 1952 the catch increased with increasing reduction capacity. From 1952 onwards, when the capacity first increased and then remained constant, the catch followed a different trend, quite independent of the reduction capacity.

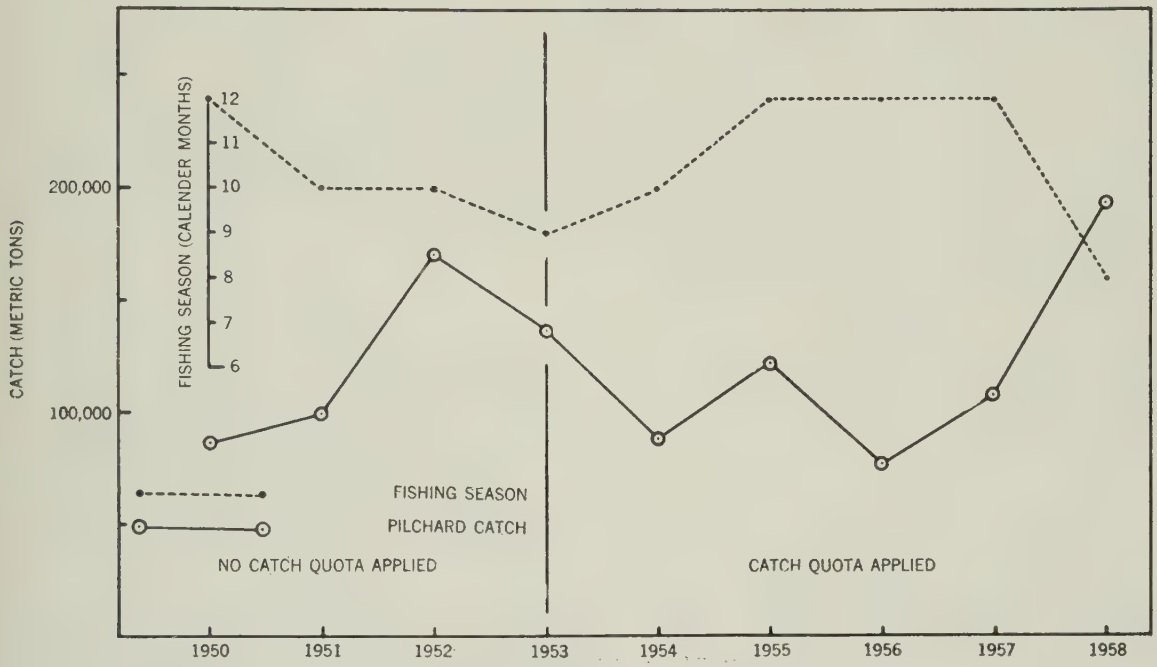
From this it appears that the pegging of the plant capacity at the particular level of 221 metric tons of raw fish per hour had no perceptible stabilising influence on the trend in the pilchard catch during the period 1952–58. During the 1950–52 period the catches were apparently affected to some degree by reduction capacity. Had the latter been at 221 tons during these early years, the upward trend in the catch over the 1950–51–52 interval would probably have been less pronounced.

(iii) *The closed fishing season.*

In Fig. 6 the pilchard catch and the total number of calendar months during which fishing took place are plotted for each year.

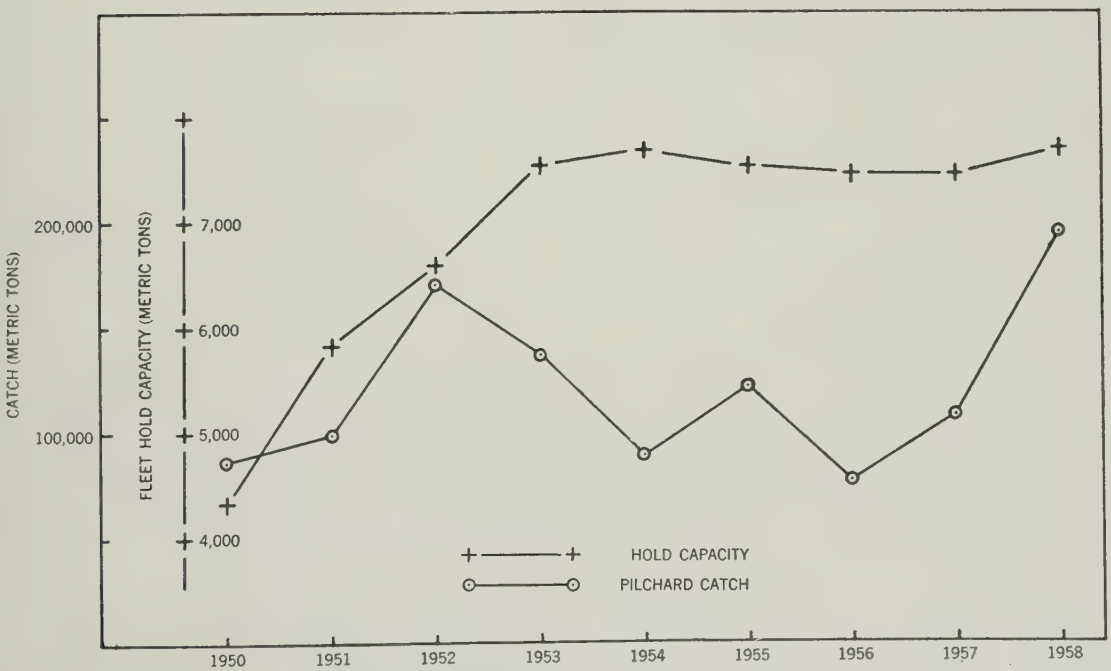
In general it appears that a short fishing season coincides with a relatively large catch and vice versa. Although it is axiomatic that longer fishing seasons in the years 1950 through 1954 and again in 1958 would have resulted in larger catches for those years, such increases would have been relatively small because catches during the second half of the year were consistently small compared with those in the first half (see Table I). It is therefore improbable that the general trend in the catch over the whole period 1950–58 would have been different, had longer fishing seasons been permitted.

FIGURE 6



Trigsurvey, 1959. DURATION OF FISHING SEASON AND THE PILCHARD CATCH, 1950–58 Government Printer, 1959.

FIGURE 7



HOLD CAPACITY OF THE FISHING FLEET AND THE PILCHARD CATCH, 1950–58.

Trigsurvey, 1959. Government Printer, 1959.

(iv) *The limitation of fishing boats.*

Fig. 7 shows the total hold capacity of the fishing fleet and the pilchard catch in each year. (The boat statistics for 1950 and 1951 are less reliable than for the rest of the period.)

As in the case of reduction plant capacity, the size of the catch was apparently influenced by the rapidly growing fishing fleet during 1950–52, whilst during the period 1952–58 the size of the fleet at the given level had apparently no stabilising effect on the trend in the catch.

Whether the catch trend over the 1950–51–52 interval would have been different if the fishing fleet had been of a similar size and composition as during 1952–58, is an open question.

(v) *The limitation of canneries.*

This control measure need not be considered as a possible influencing factor because it became effective after boat limitation had been introduced.

(vi) *The annual catch quota.*

The quota was applied for the first time in 1953 and it had a positive limiting effect on the catch in that year and again in 1954 (coupled with the closed season and economic factors) and 1958. In each of these three years the pilchard catch would have been larger, had there been no catch quota in existence. In the years 1955 through 1957 the quota could not be fulfilled despite all-out efforts by the fishing fleet.

It is possible to make allowance for the depressing effect of the quota on the catches during 1953, 1954 and 1958 by adding the average quantities of pilchards landed during the last three or four months of other years when no quota or closed season was applied. These adjustments, although raising the catches for 1953, 1954 and 1958, do not, however, change the general trend in the catch over the period 1953–58 during which the quota was applied.

2. Legal regulation and the trend in the size composition of the catch.

The only control measure that may be expected to have a direct bearing on the size composition of the catch is the prescribed mesh size for fishing nets.

However, since the minimum size of mesh remained practically constant at 32 mm. throughout the period 1950–58, the changes in the size composition of the catch, as shown by the data on length frequencies in Table VI and Fig. 8, cannot be attributed to differentiating mesh selection.

3. The influence of economic factors.

Generally speaking the demand for the products derived from the pilchard fishery was consistently good. Such short-term fluctuations in demand as did periodically occur, never acted as a restriction on the fishing effort. This is understandable as the whole catch is marketed in preserved form, thus rendering the fishery relatively insensitive to a fluctuating level in demand for its products.

There was one instance, however, when the pilchard catch was decidedly affected by a particularly heavy demand for canned maasbanker. This was in 1954 when the latter commodity sold at such an excellent price in the U.S.A. that South African fishermen were induced to concentrate on catching maasbanker.

It will be noticed that, subsequent to the imposition of the catch quota, 1954 was the only year in which the maasbanker catch exceeded the pilchard catch (see Table I). There can be little doubt that this exception to the rule is to some extent due to the much increased demand for canned maasbanker at that time and it is estimated that the 1954 pilchard catch could have been some 20,000 tons more than the actual 88,301 tons recorded.

The inflated maasbanker catch of 1954 can therefore be taken as largely responsible for the sharp downward turn in the trend of the pilchard catch from 1953 to 1954 and for the fairly steep upward turn from 1954 to 1955 (see Fig. 4). Had there been no catch quota and had the demand for canned maasbanker been normal in 1954, the trend in the pilchard catch would have sloped more gently over the 1953–54–55 interval.

4. The influence of technological factors.

In the course of the nine years from 1950 to 1958 various changes took place in the technology

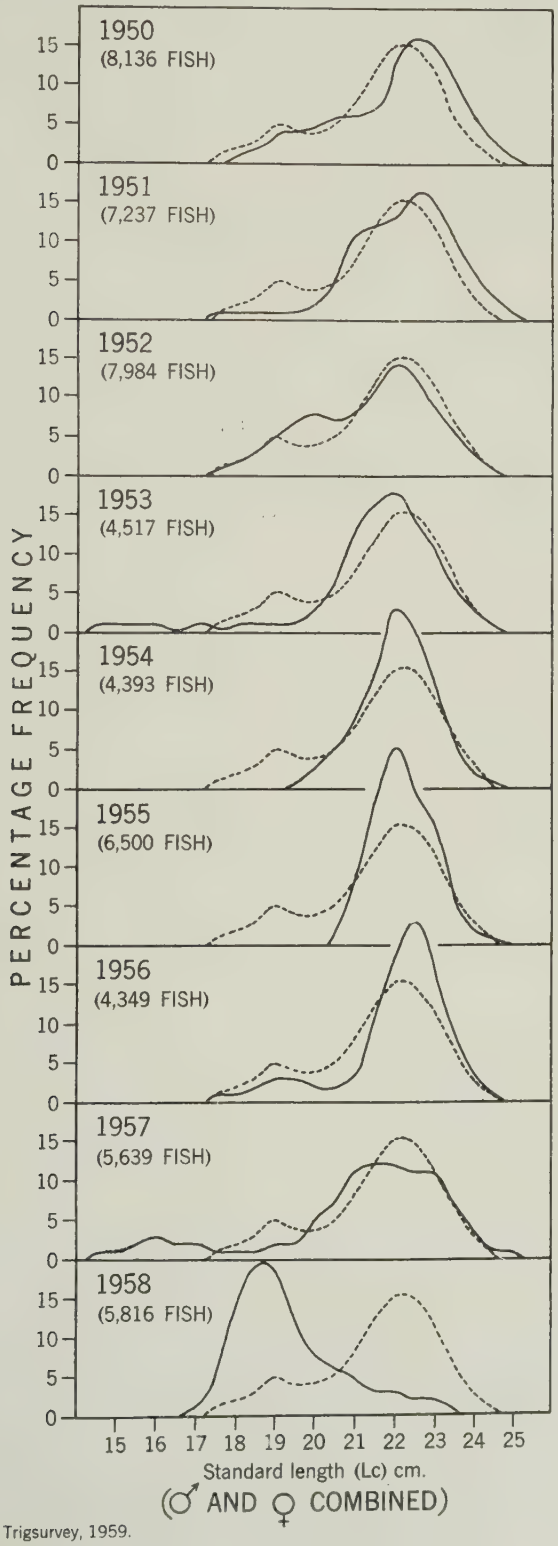


FIGURE 8

SIZE COMPOSITION OF THE PILCHARD CATCH, 1950—58

ANNUAL

1950-58 AVERAGE

Trigsurvey, 1959.

Government Printer, 1959.

of fishing and processing. Boats were gradually equipped with fishing aids such as echo-sounders and more efficient winching systems, while nets increased in size. The tendency to build bigger boats with wider ranges became prevalent. On the processing side reduction plants and canneries were continually modernized, particularly with a view to dealing with those occasions when catches were at a peak and demanded an increased rate of processing from factories.

This technological progress was most marked during the period 1952–56, i.e. during the years that the pilchard catch showed the notable downward trend. It is therefore logical to conclude that the gradually improving technology of fishing and processing at most did no more than decrease the slope of the downward trend of the pilchard catch over the period 1952–56 and probably increased the slope of the upward trend in 1957 and 1958.

From the foregoing sections of this chapter it is seen that the fishery was subject to a number of rapidly changing influencing factors during 1950 and 1951 and it is not considered possible to assess with reasonable certainty the effect of these factors on the trend in the pilchard catch during these years.

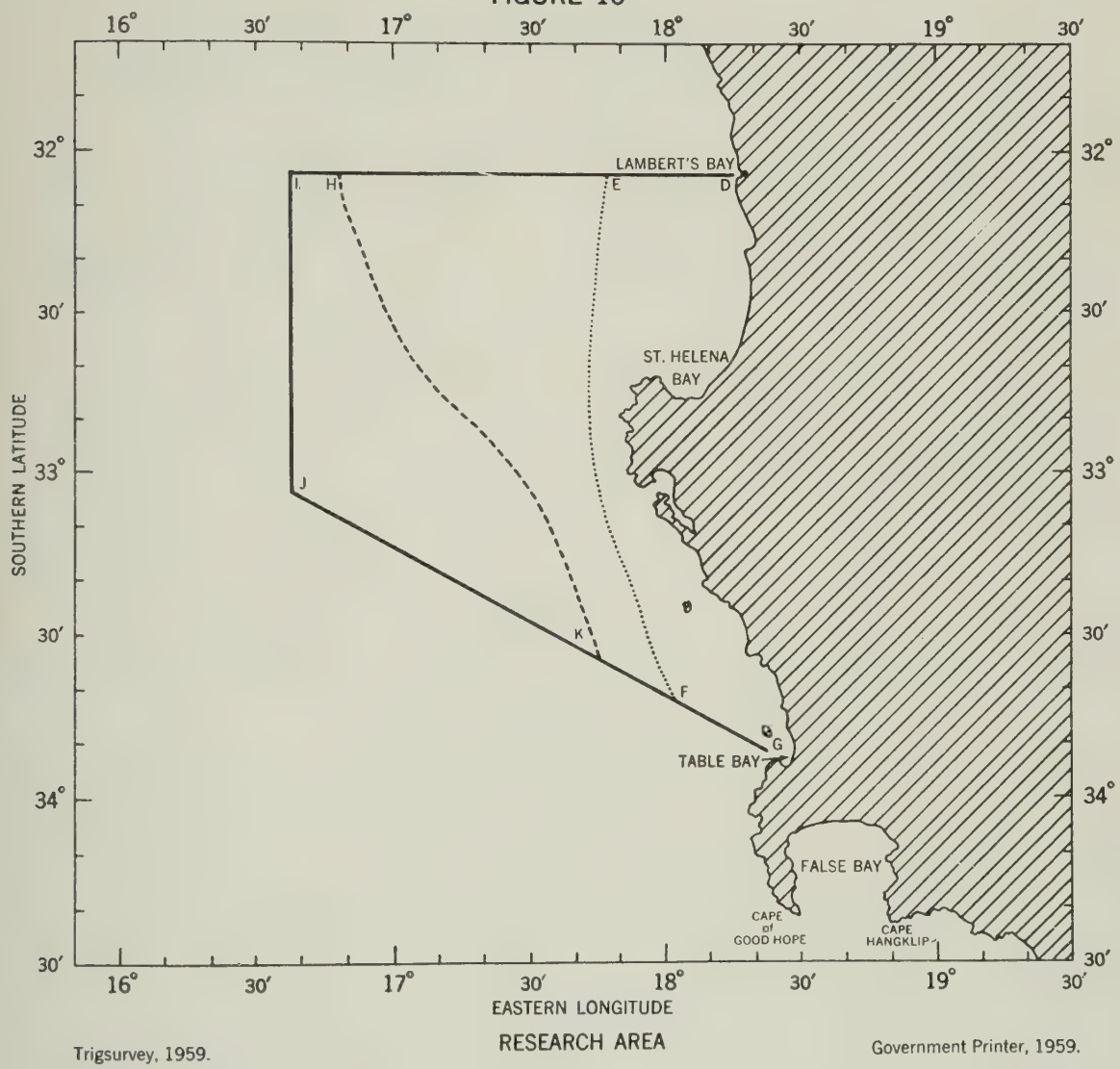
During the period 1952–58, the influence of the relevant factors can be readily assessed. The combined effect of these abiotic factors is not considered significant to the extent of having inverted the trend in the catch during any interval of the 1952–58 period. In other words, the catch trend, as shown in Fig. 4, may be regarded as a fairly reliable reflection of the availability of pilchards over 14 cm. in standard length during these seven years.

It is probable that the economic factor mentioned in section 3 of this chapter affected the slope of the catch trend for 1953–54–55 to a con-

FIGURE 9

Trigsurvey, 1959. Government Printer, 1959.

FIGURE 10



siderable degree. Fig. 9, in which an appropriate adjustment has been made for this, is regarded as a better reflection of the availability of pilchards in the relative sense.

In the next chapter the term "availability" refers to the representation given in Fig. 9.

7. Correlations between the Availability of Pilchards and Certain Natural Factors, 1952–58.

As was mentioned earlier in this paper, a programme of intensive research on the South African pilchard was begun during 1950. In the first two years the research operations were in many respects exploratory in character and beset with teething troubles. It is therefore difficult to compare findings obtained during 1950 and 1951 with those made in later years when research progressed more smoothly along a standard pattern. For this reason, and also because of the uncertainty attached to the relative availability of pilchards during 1950 and 1951, the correlations outlined below are only for the seven-year period 1952–58, or part of it. Furthermore, these correlations do not by any means cover all the factors investigated in the

research programme, but are limited to those which reveal relationships of apparent significance.

The geographic coverage of the research operations changed periodically, but one area was covered in every month of the years 1952 through 1958, with only a few exceptions during 1957 and 1958. Throughout the period 1952–58 the bulk of the commercial catch came from the inshore portion of this research area, shown as DIJG in Fig. 10. All the scientific data used in the undermentioned correlations were obtained from the coverage of this area, or part of it as indicated at the appropriate places.

I. Recruitment.

(i) *Eggs.*

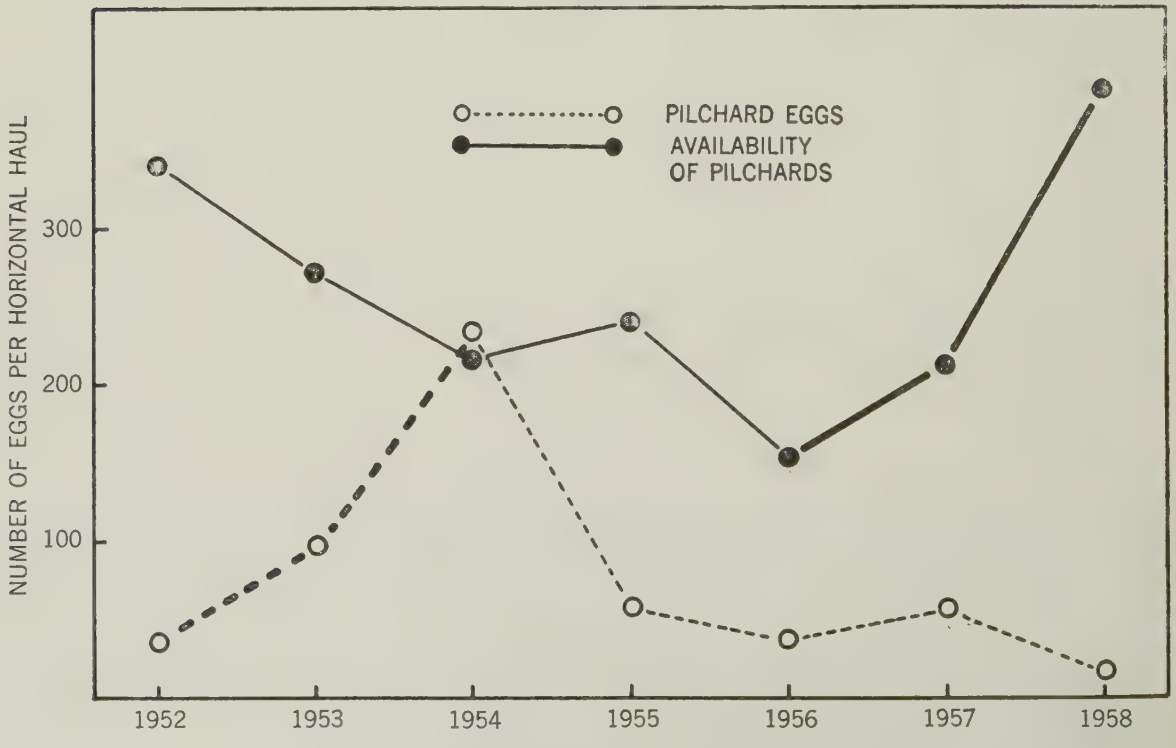
Table VII gives the yearly numbers of pilchard eggs found in the whole research area (DIJG) during the period 1952–58. Details of the gear and methods used for the collection of the eggs are as described by Davies (1954).

Fig. 11, which shows the relative abundance of eggs, or spawning intensity, and the availability of pilchards, has to be analysed against the background of the size composition of the catch (see Fig. 8) and the relationship between the size and the age of the pilchard.

Davies (1958) gives the following tentative relationship between size and age:—

Standard length (*cm.*) (*Average for males and females*).	*Age* (*Years*).
11·7	1
15·6	2
18·6	3
20·7	4
21·7	5
23·3	6

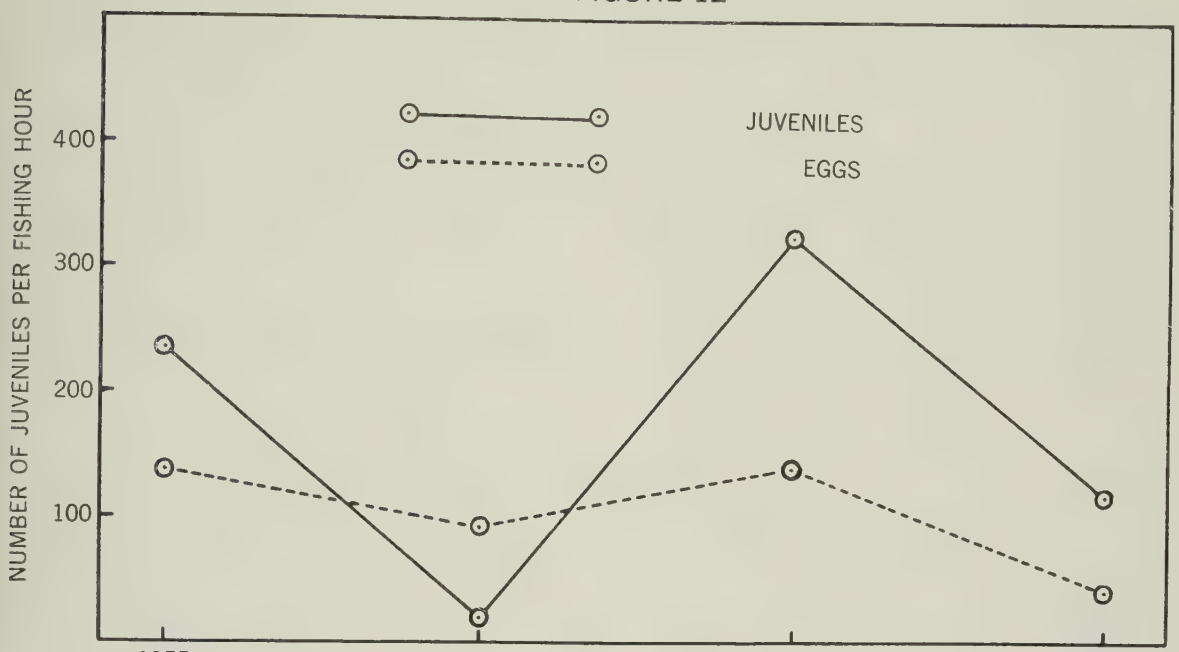
FIGURE 11



RELATIVE ABUNDANCE OF PILCHARD EGGS AND THE AVAILABILITY OF PILCHARDS, 1952–58

Trigsurvey, 1959. Government Printer, 1959.

FIGURE 12



RELATIVE ABUNDANCE OF PILCHARD EGGS AND JUVENILES, 1955–58.

Trigsurvey, 1959.

Government Printer, 1959.

Based on these data the approximate age of the dominant group of pilchards in the catch for each year of the period 1952–58 was: 1952—5 years, 1953—4 to 5 years, 1954—5 years, 1955—5 years, 1956—5 to 6 years, 1957—4 to 5 years, 1958—3 years. Allowing for the appropriate time intervals, the availability of pilchards and the intensity of spawning should be correlated in the following manner: 1958 with 1955, 1957 with 1952 and 1953, 1956 with 1950 and 1951, etc. No apparent relationship is revealed by comparing the two factors on this basis.

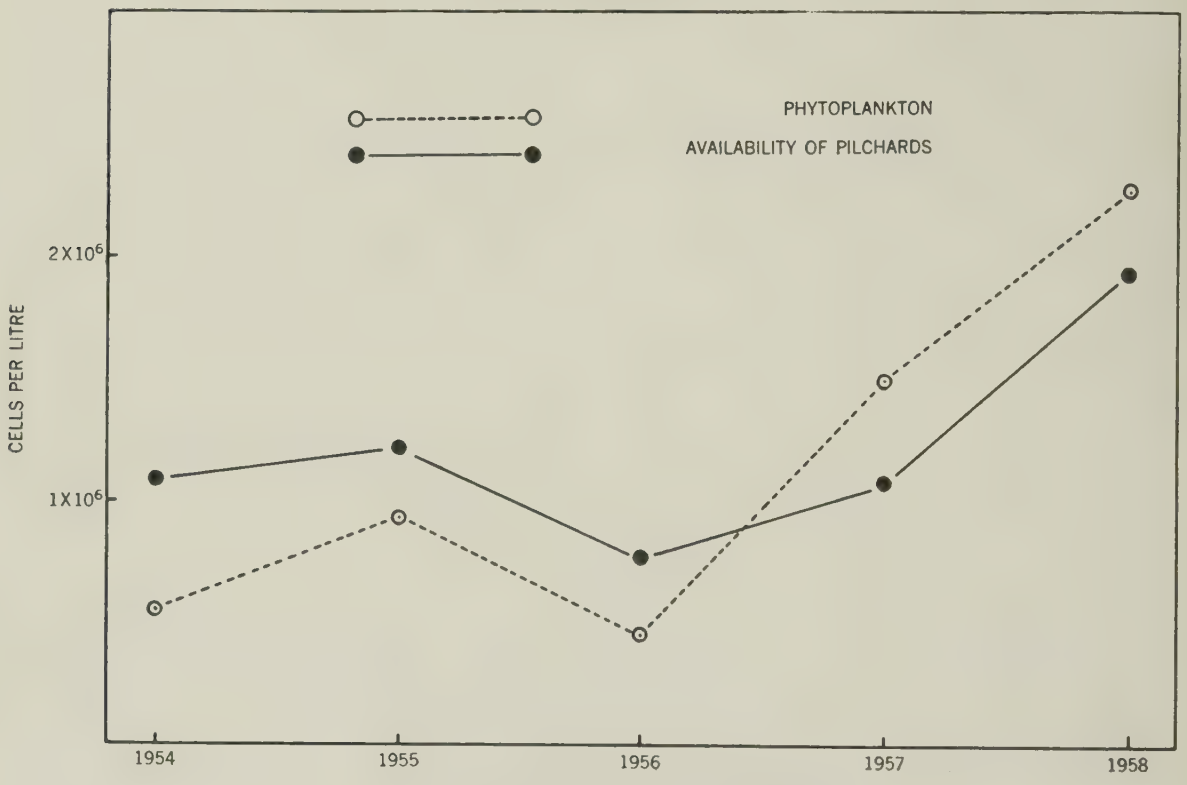
Correlating the spawning intensity with the availability of pilchards on the basis of a four-year interval between the two factors, results in a clear linear relationship—see the accentuated parts (1952–54 and 1956–58) of the graphs in Fig. 11. However, in the absence of conclusive data on the age-length relationship of the pilchard and on account of the limited period for which correlation between spawning intensity and availability is possible, the significance of this four-year interval relationship cannot yet be assessed.

A comparison between the spawning intensity in each year and the availability of pilchards in that year indicates broadly an inverse relationship between the trends in the two factors, more particularly for those years when the availability was relatively high, namely 1952–55 and 1957–58. A possible explanation for this is that, with the exceptions of 1954 and 1956, the commercial catch each year eliminated a relatively large fraction of the total spawning stock present in the fishing area.

(ii) *Juveniles.*

Table VIII gives the relative abundance of juvenile pilchards for 1955–58 as obtained from young fish surveys with a blanket-net as fishing gear, as described by Davies (1957), in the area marked DEFG in Fig. 10. In Fig. 12 the relative abundance of juveniles and spawning intensity are plotted together.

FIGURE 13



RELATIVE ABUNDANCE OF PHYTOPLANKTON AND THE AVAILABILITY OF PILCHARDS, 1954–58

Trigsurvey, 1959.

Government Printer, 1959.

It is seen that the relative abundances of juveniles and eggs show similar trends during the four-year period for which the comparison is possible. In view of the fact that the catch of juveniles consisted predominantly of fish less than one year old (see Table VIII), the almost direct relationship between the relative abundance of eggs and juveniles is not unexpected. The approximate linearity of the relationship suggests a fairly consistent survival rate of eggs to the stage of one-year old fish, except in 1956 when the mortality rates of eggs and further developmental stages were apparently high compared with the other three years.

2. Food.

(i) *Phytoplankton.*

From 1954 phytoplankton was determined quantitatively, as described by de Jager (1957). In Table IX the cell counts refer to samples obtained by means of a Nansen-Petterssen sampling bottle in area DEFG (Fig. 10).

Fig. 13 shows the relative abundance of phytoplankton and the availability of pilchards for the period 1954–58.

The direct relationship between these two factors not only confirms previous findings regarding the diet of the pilchard, as reported by de Jager (1954) and Davies (1957), but also indicates that during the period 1954–58 the relative abundance of phytoplankton, at the concentration level peculiar to this period, was highly significant in relation to determining the availability of pilchards.

(ii) *Zooplankton.*

Table X gives the settled volume of zooplankton in the whole research area (DIJG) for each year

during the period 1952–58. De Jager (1954) gives an account of the collecting of the samples and of the method for determining the settled volume.

From Fig. 14 it is seen that the relative abundance of zooplankton and the availability of pilchards are linearly related from 1953 onwards. This relationship probably has the same significance as that between phytoplankton and the availability of pilchards. No ready explanation can be offered for the inverse relationship between the relative abundance of zooplankton and the availability of pilchards during the 1952–53 interval.

3. Sea temperature.

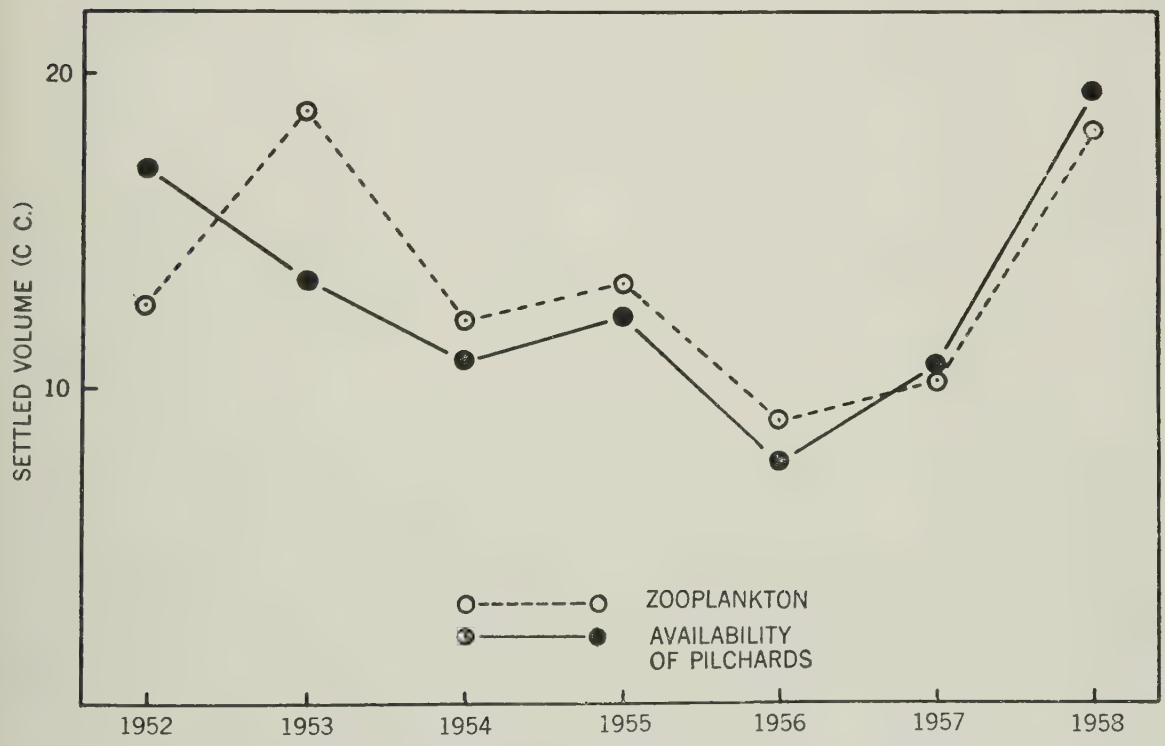
In Table XI the annual and autumn temperatures of the 0–50 metres layer in the area marked HIJK in Fig. 10 are given for the period 1951–57. The annual values refer to calendar years, while autumn is taken as March, April and May. An account of the collecting and processing of these temperature data is given by Buys (1957).

The latter author has recently found that a linear relationship exists between the following factors:—

(i) the annual temperature of the 0–50 metres layer in area HIJK and the size of the pilchard catch in the following year, the year being taken from September through August;

(ii) the autumn temperature of the 0–50 metres layer in the same area and the size of the pilchard catch in the autumn of the following year.

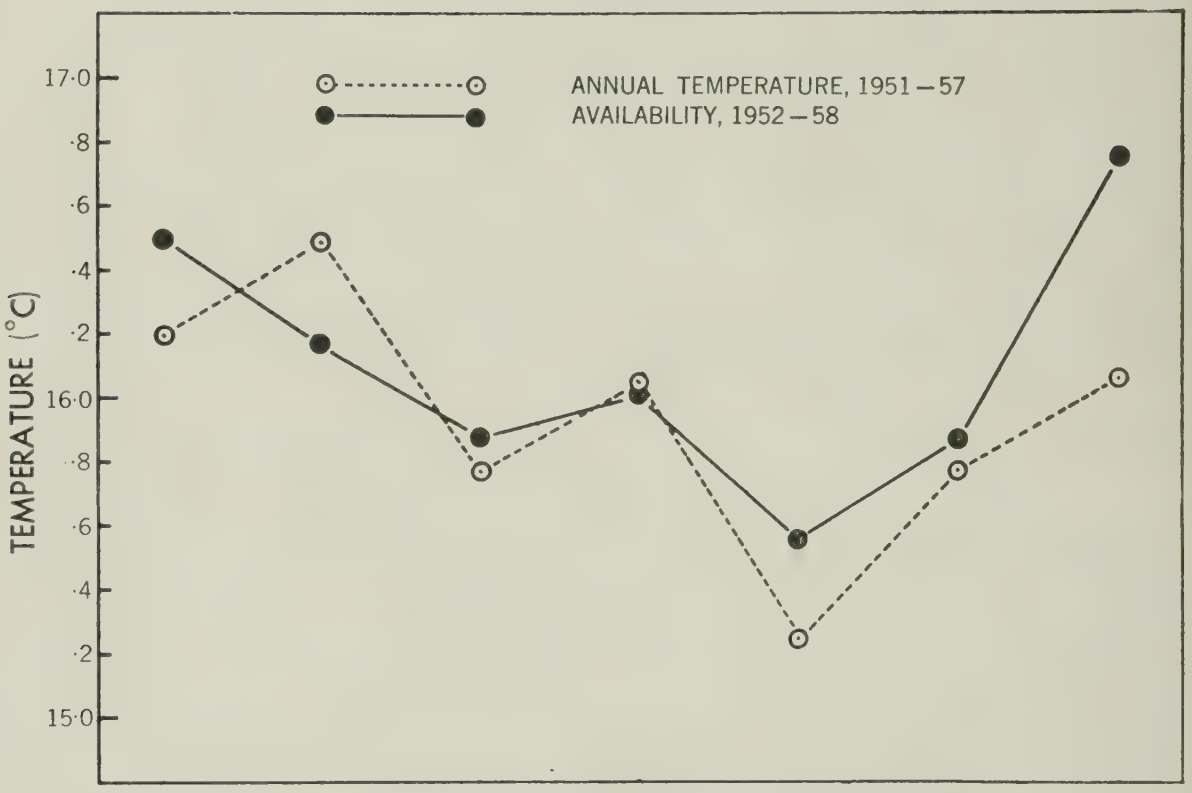
FIGURE 14



RELATIVE ABUNDANCE OF ZOOPLANKTON AND THE AVAILABILITY OF PILCHARDS, 1952–58

Trigsurvey, 1959. Government Printer, 1959.

FIGURE 15



0–50 metres ANNUAL TEMPERATURE, 1951–57, AND THE AVAILABILITY OF PILCHARDS, 1952–58.

Trigsurvey, 1959. Government Printer, 1959.

A detailed report on this subject is given by Buys (1959).

In Fig. 15 the temperature values are on a calendar year basis and it is seen that, as in the case of (i) above, the 0–50 metres temperature during the period 1952–57 follows a similar trend to that shown by the availability of pilchards during 1953–58.

When the autumn temperature of the 0–50 metres layer is compared with the availability of pilchards in the following calendar year, a remarkably clear linear relationship is obtained (see Figs. 16 and 17). The correlation coefficient for this temperature—availability function is 0·98 for the six years from 1952 to 1957 and 0·79 for the seven-year period 1952–58. The difference in the correlation coefficients for the two periods suggests the occurrence of exceptional conditions during 1958. Without going into detail, two unusual facts, probably not unconnected, were noticeable in 1958, namely, increased catches in the area between Table Bay and Cape Hangklip and a sharp decrease in the dominant size of pilchards present in a commercial catch which was the largest in the whole history of the fishery.

The existence of the linear function shown in Fig. 17 means that, during 1952–57, the size of the pilchard catch for any year could have been forecast with a high degree of accuracy some six months before the year's fishing began, simply on the strength of the autumn temperature of the upper

50 metres of sea-water in the area HIJK. For 1958 a forecast on this basis would have been less accurate but still fairly reliable.

It is clear that the availability of pilchards was not affected directly by the temperature changes—covering the narrow range of only 2·3°C—but by a combination of factors of which the fluctuating temperature was a symptom. The processes involved in relating availability to temperature in the manner described are not at present clearly understood, but the fact remains that the temperature—availability relationship itself was highly significant during 1952–58 and it remains to be seen whether it will have the same significance in future years.

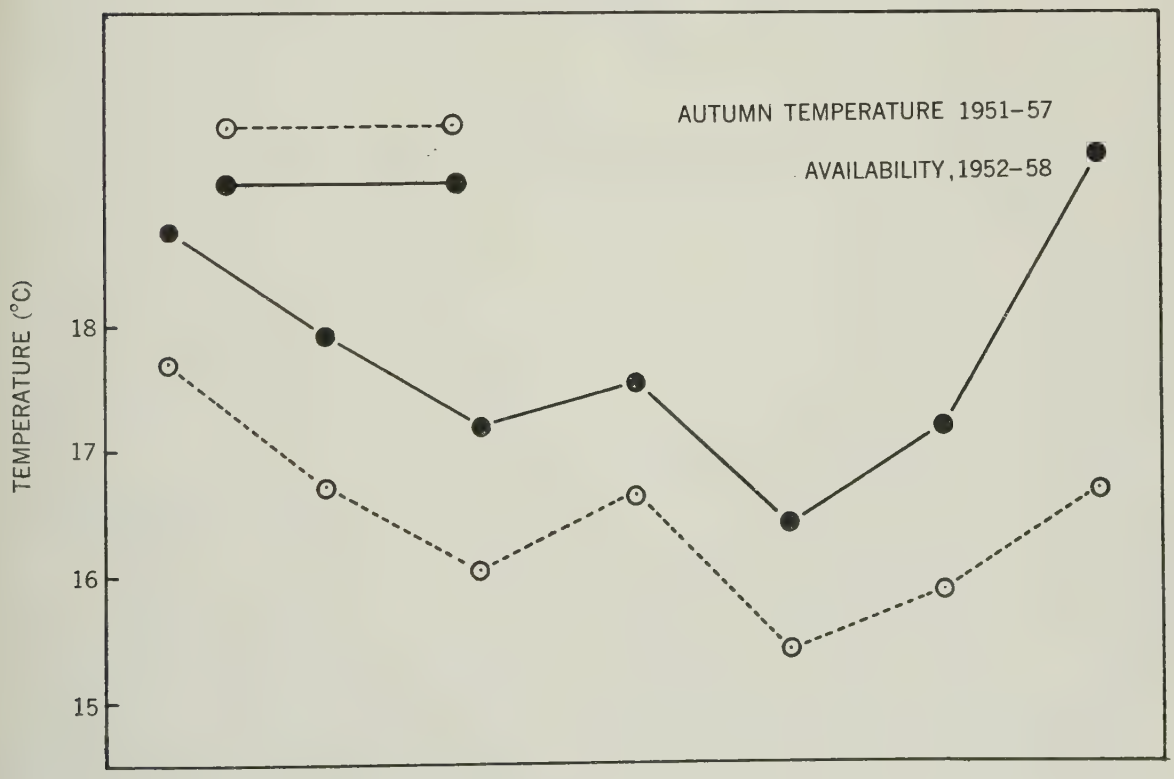
The autumn temperature for 1958—based on the observations of one month (April) only—was 17·30°C and from a statistical analysis of the relevant data in Tables I and XI, the pilchard catch for 1959 may be expected to fall within the range of 150,000 to 200,000 metric tons.

8. Acknowledgments.

The author is indebted to the scientists and research vessels' personnel of the Division of Fisheries who took part in the collecting and processing of the data used in this paper. The value of the co-operation received by the Division from the fishing industry and the fishermen in obtaining the essential fishery statistics cannot be over-stressed.

A special word of thanks is due to the late Dr. J. M. Marchand, former Director of Fisheries, and to Dr. A. J. Clowes and Messrs. B. v. D. de Jager, and M. E. L. Buys of this Division for assistance and criticism.

FIGURE 16

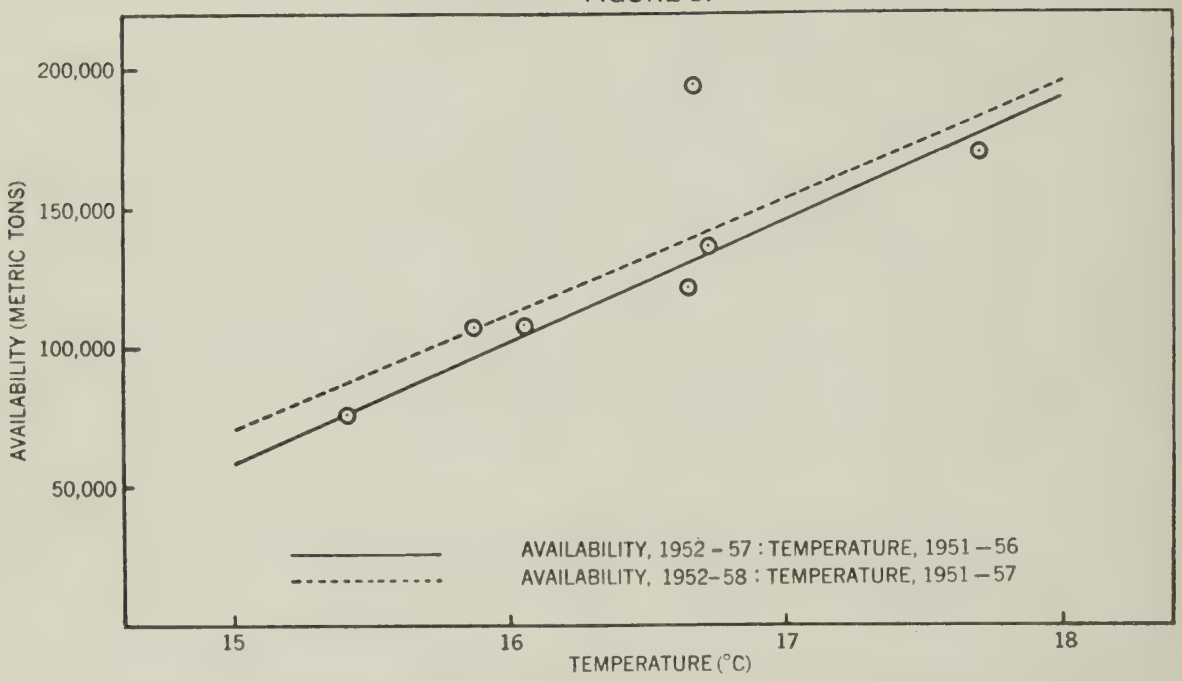


0–50 metres AUTUMN TEMPERATURE, 1951–57, AND
THE AVAILABILITY OF PILCHARDS, 1952–58

Trigsurvey, 1959.

Government Printer, 1959.

FIGURE 17



REGRESSION LINES OF PILCHARD AVAILABILITY ON THE AUTUMN TEMPERATURE OF THE 0–50 Metres WATER LAYER IN THE PREVIOUS YEAR

Trigsurvey, 1959. Government Printer, 1959.

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TABLE I.—Monthly Catches of Pilchards and Maasbanker, 1950–58.

P=Pilchard. M=Maasbanker. P and M=Pilchard and Maasbanker.

Year.	Fish.	Catch (Metric tons).												
		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Jan.–Dec.
1950...	P	Nil.	2,307	3,074	5,263	14,038	12,477	9,055	14,962	7,660	467	14,053	2,910	86,266
	M	5,925	8,641	13,569	2,560	3,482	4,574	683	417	225	1,702	3,024	5,550	50,352
	P and M	5,925	10,948	16,643	7,823	17,520	17,051	9,738	15,379	7,885	2,169	17,077	8,460	136,618
1951.....	P	439	1,090	7,446	10,557	13,277	14,211	22,699	20,438	No fishing.	No fishing.	8,896	383	99,436
	M	14,446	16,932	11,713	8,886	13,695	4,884	9,610	3,054	1,695	411	11,969	3,669	100,964
	P and M	14,885	18,022	19,159	19,443	26,972	19,095	32,309	23,492	1,695	411	20,865	4,052	200,400
1952.....	P	2,250	11,023	30,068	37,909	25,278	14,108	25,784	7,099	No fishing.	No fishing.	16,406	102	170,027
	M	15,797	22,592	8,316	7,204	6,817	8,990	8,967	519	No fishing.	No fishing.	19,814	3,620	102,636
	P and M	18,047	33,615	38,384	45,113	32,095	23,098	34,751	7,618	No fishing.	No fishing.	36,220	3,722	272,663
1953.....	P	487	16,141	31,102	20,543	34,480	6,633	9,380	4,175	14,030	No fishing.	No fishing.	No fishing.	136,972
	M	17,984	18,154	10,319	3,367	4,239	12,372	9,754	4,318	3,988	No fishing.	No fishing.	No fishing.	84,495
	P and M	18,471	34,295	41,421	23,910	38,719	19,005	19,134	8,493	18,018	No fishing.	No fishing.	No fishing.	221,467
1954.....	P	1,593	2,977	8,039	13,355	34,399	16,633	8,094	913	No fishing.	No fishing.	2,238	60	88,301
	M	22,973	15,918	17,002	16,136	11,698	17,854	12,661	73	No fishing.	No fishing.	3,401	423	118,139
	P and M	24,566	18,895	25,041	29,491	46,097	34,487	20,755	986	No fishing.	No fishing.	5,639	483	206,440
1955.....	P	32	20,383	43,458	8,194	15,495	10,941	3,526	5,727	12,548	630	1,000	15	121,949
	M	4,291	14,103	2,108	20,982	16,889	718	16,655	566	1,849	36	479	144	78,820
	P and M	4,323	34,486	45,566	29,176	32,384	11,659	20,181	6,293	14,397	666	1,479	159	200,769
1956.....	P	3,297	6,543	21,961	18,487	2,732	420	6,306	9,306	6,042	1,246	1	4	76,345
	M	21	538	643	3,242	7,570	836	17,880	8,572	2,496	397	2,701	674	45,570
	P and M	3,318	7,081	22,604	21,729	10,302	1,256	24,186	17,878	8,538	1,643	2,702	678	121,915
1957.....	P	4,286	16,297	23,217	15,327	7,931	1,243	1,764	6,905	5,216	8,140	12,791	4,434	107,551
	M	637	3,958	3,668	2,579	37,827	31,838	366	679	1,323	1,412	273	5	84,565
	P and M	4,923	20,255	26,885	17,906	45,758	33,081	2,130	7,584	6,539	9,552	13,064	4,439	192,116
1958.....	P	6,976	22,764	20,896	49,262	11,420	35,835	23,236	24,227	No fishing.	No fishing.	No fishing.	No fishing.	194,616
	M	136	1,187	70	12,620	38,090	2,586	1,006	726	No fishing.	No fishing.	No fishing.	No fishing.	56,421
	P and M	7,112	23,951	20,966	61,882	49,510	38,421	24,242	24,953	No fishing.	No fishing.	No fishing.	No fishing.	251,037

TABLE II.—Annual Catches of Pilchards and Maasbanker, 1950–58.

Year.	Pilchard catch (metric tons.)	Maasbanker catch (metric tons).	Pilchard and Maasbanker catch (metric tons).	Pilchard catch as a percentage of the Pilchard and Maasbanker catch. (Percentage).
1950	86,266	50,352	136,618	63·1
1951	99,436	100,964	200,400	49·6
1952	170,027	102,636	272,663	62·4
1953	136,972	84,495	221,467	61·8
1954	88,301	118,139	206,440	42·8
1955	121,949	78,820	200,769	60·7
1956	76,345	45,570	121,915	62·6
1957	107,551	84,565	192,116	56·0
1958	194,616	56,421	251,037	77·5
1950–58 Average	120,163	80,218	200,381	59·6

TABLE III.—Annual Deviation from the Average Pilchard Catch, 1950–58.

Year.	Pilchard catch (metric tons).	Average pilchard catch, 1950–58.	Annual deviation from the average catch.	
			Metric tons.	Per cent.
1950	86,266		−33,897	−28·2
1951	99,436		−20,727	−17·2
1952	170,027		+49,864	+41·5
1953	136,972		+16,809	+14·0
1954	88,301	120,163 metric tons.	−31,862	−26·5
1955	121,949		+ 1,786	+ 1·5
1956	76,345		−43,818	−36·5
1957	107,551		−12,612	−10·5
1958	194,616		+74,453	+62·0

TABLE IV.—Annual Deviation from the Average Maasbanker Catch, 1950–58.

Year.	Maasbanker catch (metric tons).	Average Maasbanker catch, 1950–58.	Annual deviation from the average catch.	
			Metric tons.	Per cent.
1950	50,352	80,218 metric tons.	−29,866	−37·2
1951	100,964		+20,746	+25·9
1952	102,636		+22,418	+28·0
1953	84,495		+ 4,277	+ 5·3
1954	118,139		+37,921	+47·3
1955	78,820		− 1,398	− 1·7
1956	45,570		−34,648	−43·2
1957	84,565		+ 4,347	+ 5·4
1958	56,421		−23,797	−29·7

TABLE V.—Pilchard Catch, Size of Fishing Fleet, Reduction Plant Capacity and Duration of Fishing Season, 1950–58.

Year.	Pilchard catch (metric tons).	Total hold capacity of fishing fleet (metric tons) with number of boats in brackets.	Total reduction plant capacity (metric tons of raw fish per hour).	Duration of fishing season (calendar months).
1950	86,266	4,330 (150)	178	12
1951	99,436	5,810 (183)	190	10
1952	170,027	6,590 (197)	194	10
1953	136,972	7,550 (229)	221	9
1954	88,301	7,680 (225)	221	10
1955	121,949	7,530 (228)	221	12
1956	76,345	7,450 (222)	221	12
1957	107,551	7,450 (210)	221	12
1958	194,616	7,690 (201)	221	8

TABLE VI.—Size Composition of the Pilchard Catch, 1950–58.

Standard (Lc) length of fish (cm.).	Frequency (per cent).									
	1950.	1951.	1952.	1953.	1954.	1955.	1956.	1957.	1958.	Mean.
14·0–14·4	—	—	—	—	—	—	—	—	—	—
14·5–14·9	—	—	—	1	—	—	—	1	—	—
15·0–15·4	—	—	—	1	—	—	—	1	—	—
15·5–15·9	—	—	—	1	—	—	—	2	—	—
16·0–16·4	—	—	—	1	—	—	—	3	—	—
16·5–16·9	—	—	—	—	—	—	—	2	—	—
17·0–17·4	—	—	—	1	—	—	—	2	1	—
17·5–17·9	—	1	1	—	—	—	1	1	4	1
18·0–18·4	1	1	2	1	—	—	1	1	13	2
18·5–18·9	2	1	3	1	—	—	2	1	19	3
19·0–19·4	4	1	5	1	—	—	3	2	19	4
19·5–19·9	4	1	7	1	1	—	3	2	13	4
20·0–20·4	5	2	8	3	3	—	2	5	8	4
20·5–20·9	6	5	7	6	5	2	2	7	6	5
21·0–21·4	6	11	8	13	9	9	3	11	5	9
21·5–21·9	7	12	11	16	15	18	10	12	3	12
22·0–22·4	13	13	14	18	23	25	18	12	3	16
22·5–22·9	16	16	13	14	20	20	23	11	2	15
23·0–23·4	15	15	9	11	14	16	18	11	2	13
23·5–23·9	11	11	6	6	7	7	9	7	1	7
24·0–24·4	6	6	3	3	2	2	4	4	1	4
24·5–24·9	3	3	1	1	1	1	1	1	—	1
25·0–25·4	1	1	—	—	—	—	—	1	—	—
25·5–25·9	—	—	—	—	—	—	—	—	—	—

TABLE VII.—Relative Abundance of Pilchard Eggs, 1952–58.

Year.	Pilchard eggs.			
	Total collected in all nets.	Total collected in horizontal surface hauls.	Number of horizontal hauls.	Number of eggs per horizontal haul.
1952	18,547	7,875	233	34
1953	30,157	25,723	270	95
1954	92,790	66,032	285	232
1955	21,442	16,294	296	55
1956	19,884	10,735	294	37
1957	15,896	9,691	172	56
1958	2,293	918	137	17

TABLE VIII.—Relative Abundance of Juvenile Pilchards, 1955–58.

Year.	Number of juvenile pilchards caught.	Number of fishing hours.	Number of juveniles/fishing hours.	Dominant length group, Lc. (cm.).	Dominant year-class (age in years).
1955	6,932	29·5	235	3·5–4·5	<1
1956	1,237	67·5	18	6·5–7·5	<1
1957	11,568	35·5	326	8·0–9·0	<1
1958	16,037	137·5	117	5·5–6·5	<1

TABLE IX.—Relative Abundance of Phytoplankton, 1954–58.

Year.	Number of samples taken at 5 metres depth.	Total phytoplankton per sample (cells/litre).
1954	24	557,291
1955	33	930,879
1956	36	422,847
1957	71	1,494,945
1958	91	2,261,125

TABLE X.—Relative Abundance of Zooplankton, 1952–58.

Year.	Number of vertical net hauls from 100 metres to surface.	Total zooplankton per haul (settled volume in cc.).
1952	228	12·7
1953	276	18·8
1954	276	12·1
1955	276	13·3
1956	324	8·9
1957	189	10·2
1958	126	18·2

TABLE XI.—Annual and Autumn Temperatures of the 0–50 Metres Layer of Sea-water, 1951–57.

Year.	Annual Temp. (°C).	Autumn Temp. (°C).
1951	16·20	17·70
1952	16·49	16·72
1953	15·77	16·05
1954	16·05	16·65
1955	15·25	15·41
1956	15·77	15·87
1957	16·06	16·67